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Evaluation of Infrared Tympanic Thermometers during Normothermia and Hypothermia in Humans

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INTRODUCTION

Infrared tympanic thermometers (ITTs) are becoming commonplace in hospitals and laboratories for routine measurement of deep body temperature. Concerns have been raised, however, regarding their accuracy when compared to other body temperature estimates. Some authors have reported the ITTs to be accurate to within 0.1°C[1] and closely related to other measures of deep body temperature,[1–3] while others have reported some inaccuracy[4] (± 0.5°C) and poor correlation.[5]

The objective of the present study was to evaluate three brands of ITTs (Genius®; Thermoscan®; and Diatek®) on normothermic and hypothermic subjects against various estimates of core temperature: oral (T_{oral}), rectal (T_{re}), esophageal (T_{eso}), and ear canal (T_{ec}).

MATERIAL AND METHODS

Normothermia Experiment

Sixty-six males (mean ± SE: 38.1 ± 1.3 years of age) and 29 females (34.0 ± 1.8 years) for a total of 95 normothermic subjects (mean oral temperature of 36.80 ± 0.03°C) participated in this study. They had their right ear canal characterized by a physician using an othoscope (Heine micro-tip, Germany; outside diameter of the cone-tip: ~7.0 mm). The anatomical characterization was done for the

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length of the ear canal, its diameter, curvature, presence of ear canal or tympanum inflammation, level of obstruction by cerumen, and percentage of the field of view covered by the tympanum (at ± 5% accuracy). Following the ear examination, the right tympanic temperature was measured three times by each of the three investigators using each of three different ITT instruments (FirstTemp Genius model 3000A, Intelligent Medical Systems, CA; Thermoscan model IR-1, Thermoscan Inc., CA; and Diatek model 9000, Diatek Inc., CA) within a 15-min period. The sequence of instruments was randomly assigned among the subjects. During the 15-min period, the oral temperature was also measured using a small thermistor (YSI 44004 series, Yellow Spring Instruments, OH) located in a posterior sublingual pocket of the subject's mouth. The oral temperature was recorded at the end of the 15-min period. The subjects were asked to avoid ingesting any drink or food and refrain from smoking for at least 30 min before the measurements. During the 15-min measurement period, the subjects were asked to breathe through their nose and keep their mouth closed. The temperature measurements were performed at room temperature (23.0 ± 0.2°C) while the subjects were in a sitting position. Prior to the measurement, the ITT instruments were checked for calibration against a calibrated quartz thermometer (Hewlett Packard 2804A) and were found to be accurate to 0.1°C. The calibration of the oral thermistors was checked to be within 0.1°C of the ITT instruments. All three ITT instruments were used at the "surface mode" setting which gave the actual temperature of the surface scanned.

Hypothermia Experiment

In a second study, 10 males (29.9 ± 1.3 years of age) and 3 females (25.9 ± 4.4 years) were tested. The subjects were fully informed of the procedures and possible risks of the study and their right to withdraw from the experiment at any time without prejudice. Written informed consent was obtained from all subjects before experimentation. The protocol was approved by Institutional Ethics Committees.

The subjects were asked to abstain from smoking and using any medication, drug, or other stimulant (including caffeine and alcohol) for at least 12 h before the experiments. All experiments were performed at the same time of the day for each subject. The subjects had their right ear canal characterized by a physician using an othoscope prior to the experiment.

During the testing, the subjects were hypothermic, their T_{eso} ranging from 36.5 to 33.3°C by the end of the cold exposure. The hypothermia was induced by cold water immersion of the whole body (head out) with the water temperature ranging from 2 to 8°C and the duration of the immersion ranging from 25 to 115 minutes. During the immersion period, the tympanic temperature (T_{ty}) was measured every 5 minutes from the right ear using the same three ITTs, and the rectal, esophageal and ear canal temperatures were measured continuously by using type T thermocouples (Mon-a-therm General Purpose, Mallinckrodt Medical, St. Louis, MO). The rectal probe was positioned 15 cm into the rectum, the esophageal probe was positioned at the level of the heart using the method of Mekjavik and Rempel,[6] and the ear canal probe was positioned very close to the tympanic membrane: after touching the tympanic membrane, the probe was withdrawn just enough for the pain sensation to disappear.

The subjects were cooled on three occasions separated by a week. The temperature of the water upon entry was approximately 20°C. Following entry, ice

was added to the stirred water to lower the temperature of the water to approximately 2 to 8°C within the first 10 minutes of the immersion. The T_{ty} measurements were performed by one investigator using a different ITT instrument for each trial.

RESULTS

Normothermia Experiment

We observed that the largest difference between any of the 3 successive readings performed by the same operator using the same instrument was less than the resolution of the ITT instruments (0.09 ± 0.02°C); those three successive readings were therefore averaged. No difference was observed between the temperature readings obtained by operators 1 and 2, but both operators obtained readings on average 0.23 ± 0.03°C higher than operator 3 whose technique differed by his lighter pressure on the subject's ear canal. The oral temperature (T_{oral}) was significantly higher (by 0.92 ± 0.05°C, range −0.1 to 2.2°C; $p < 0.001$) than the tympanic temperature (T_{ty}) measured by the ITT instruments (T_{oral}: 36.80 ± 0.03°C; T_{ty}: 35.88 ± 0.05°C). There was a significant positive correlation ($p < 0.001$) between T_{oral} and T_{ty}, but the coefficient of correlation was only 0.36 ± 0.02. No difference was observed between the temperature readings of the Thermoscan and the Diatek instruments, but both instruments gave temperatures 0.20 ± 0.03°C higher than the Genius ($p < 0.001$), which has the largest cone-shaped head of the instruments tested (Genius: 9.0 mm; Thermoscan: 7.6 mm; Diatek: 8.0 mm).

Twenty-five percent of the subjects had between 50 and 100% of their tympanic membrane obscured due to the curvature of the ear canal or by cerumen, while the tympanic membrane could be entirely visualized in only 14 subjects (15%).

Hypothermia Experiment

On average during the immersion period, T_{ty} measured from the three ITTs was 1.06 ± 0.10°C lower than the other core estimates. The differences between T_{ty} and each of the three core estimates were not different, but the three differences were larger for the Genius® ITT (1.6 ± 0.2°C) compared to the two other instruments (0.7 ± 0.1°C for Diatek®; 0.8 ± 0.2°C for Thermoscan®). The average temperature difference observed between T_{ty} and the other three core estimates for the normothermic subjects (0.92 ± 0.05°C) was not different when compared to the difference observed for the hypothermic subjects (1.06 ± 0.10°C). Furthermore, the temperature differences between T_{ty} measured by ITTs and the other core estimates were not related to the level of hypothermia.

DISCUSSION

On average for the three ITT instruments, we observed that T_{ty} was 1.06 ± 0.10°C lower than the other core estimates when measured on mildly hypothermic subjects (mean T_{eso} at the end of the immersion ranging between 36.5 and 33.3°C).

The results are in agreement with the difference between T_{ty} and a T_{oral} of 0.92 ± 0.05°C observed for normothermic subjects for the same three ITT instruments. These results, however, contrast with those of Mekjavic *et al.* (1992), who reported that the FirstTemp Genius® ITT provides an adequate measure of core temperature in hypothermic subjects, although they observed temperature differences as high as 0.61°C between T_{ty} measured with ITT and T_{re}. In the study of Mekjavic *et al.* (1992), the instrument was set to "core" or "rectal" modes as opposed to the "surface" mode used in the present study (Mekjavic, personal communication). It was observed by Frim and Ducharme[7] that when ITTs are set to modes other than "surface," a mathematical algorithm converts the actual surface temperature read by the sensor into a value that might be obtained using conventional thermometry at a different deep body temperature site such as the mouth ("oral" mode), pulmonary artery or esophagus ("core" mode), or the rectum ("rectal" mode). The algorithms are generally based on statistical relationships between data obtained in clinical settings, and they can have restrictions. Furthermore, Frim and Ducharme[7] observed that the mathematical algorithms varied between instruments and as a function of both target temperature and mode setting. The displayed temperature can be as much as 1.3°C above the temperature actually read by the sensor. The authors also questioned the validity of applying a fixed mathematical expression to the variable and dynamic relationships between the various deep body temperature sites.

The infrared sensor of an ITT will register the temperature of the aural structure that it can "see" during the measurement. Several factors have been identified by Ducharme *et al.*[8] to significantly affect the sensor's view: the diameter of the probe tip, which depends on the brand of ITT used; the technique of measurement, which depends on the aiming and pressure applied by the investigator; and the characteristics of the ear canal such as the curvature, length, and presence of tympanic inflammation. These factors can more or less contribute to the contamination of the real tympanic temperature. Five subjects during the normothermia experiment had an ideal ear canal for tympanic temperature measurement using an ITT (short, straight, large diameter, absence of cerumen and inflammation); the average value of $(T_{oral}-T_{ty})$ was down to 0.15°C for those subjects compared to 0.92°C for the pool of 95 subjects. In the hypothermia experiment, none of the subjects had ideal ear canal anatomy, the majority having average diameter and length with curved ear canal, and between 0 and 20% of cerumen coverage. The ITT instruments, therefore, probably did not have an ideal view of the subject's tympanum, and this can explain part of the difference in temperature between T_{ty} readings and the other core estimates.

It was observed in the present study and by Ducharme *et al.*[8] that a significantly larger difference exists between T_{ty} and the other core estimates for the Genius® ITT when compared to the two other brands. This is attributed to the larger cone-shaped head of the Genius® ITT which precludes it penetrating deep into the subject's ear canal.

It is concluded that unless the ITT instrument has a perfect view of the tympanum (which was the case in only 5% of our subjects), it cannot provide a reliable measurement of the tympanic temperature for normothermic or hypothermic subjects.

REFERENCES

1. SHINOZAKI, T., R. DEANE & F. M. PERKINS. 1988. Infrared tympanic thermometer: evaluation of a new clinical thermometer. Crit. Care Med. 16: 148–150.

2. ERIKSON, R. & S. YOUNT. 1990. Comparison of tympanic and oral temperatures. Heart Lung 19(3): 305.
3. MEKJAVIC, I. B., J. SUN, V. LUN & G. GIESBRECHT. 1992. Evaluation of an infra-red tympanic thermometer during cold water immersion and rewarming. *In* Proceedings of the Fifth International Conference on Environmental Ergonomics. Maastricht. W. A. Lotens & G. Havenith, Eds. 42–43.
4. SCHERBENSKE, K. J. & C. A. LEDBETTER. 1993. The *in vitro* determination of the accuracy and precision of three infrared tympanic thermometers (ITTs). *In* Abstracts of the 64th Annual Scientific Meeting of Aerospace Medical Association (Toronto). A11.
5. ROS, S. P. 1989. Evaluation of a tympanic membrane thermometer in an outpatient clinical setting. Ann. Emerg. Med. 18: 1004–1006.
6. MEKJAVIC, I. B. & M. E. REMPEL. 1990. Determination of esophageal probe insertion length based on standing and sitting height. J. Appl. Physiol. 69(1): 376–379.
7. FRIM, J. & M. B. DUCHARME. 1994. Physical properties of several infrared tympanic thermometers. *In* Proceedings of the Sixth International Conference on Environmental Ergonomics. Montebello, Canada. September 25–30. J. Frim, M. B. Ducharme & P. Tikuisis, Eds. 144–145.
8. DUCHARME, M. B., J. FRIM & L. BOURDON. 1994. Infrared tympanic thermometry: methodological considerations. *In* Proceedings of the Sixth International Conference on Environmental Ergonomics. Montebello, Canada. September 25–30. J. Frim, M. B. Ducharme & P. Tikuisis, Eds. 146–147.